



# Super Hard Steel Supersonic Particle Deposition

Presented by:

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*Replacement of Hard Chrome Plating  
Program Review Meeting*

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# INEEL Super Hard Steel

Developed at the Department of Energy's Idaho National Engineering and Environmental Laboratory (INEEL)

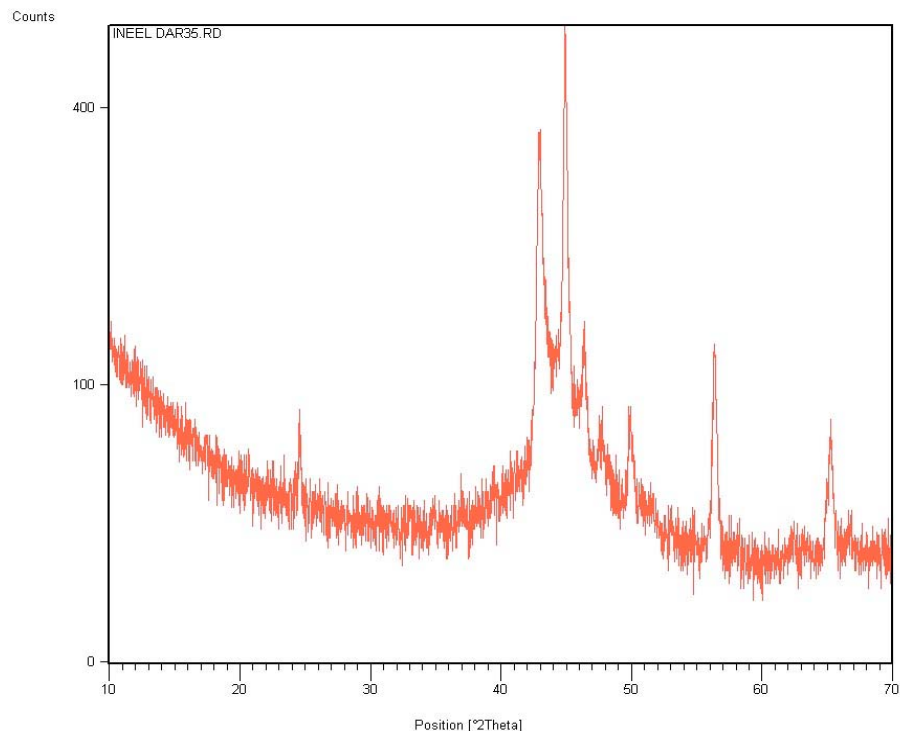
- Material forms a Metallic Glass or Nano Composite Microstructure
- Low Cost - No Exotic Elements - Uses Conventional Spray Methods

- **Composition wt%:** C-1, Mn-2, Si-1.4, Cr-20, Mo-5, W-6
- **Microstructure:** Amorphous or Nano Crystalline
- **Uses:** Wear, Corrosion and Impact Resistance

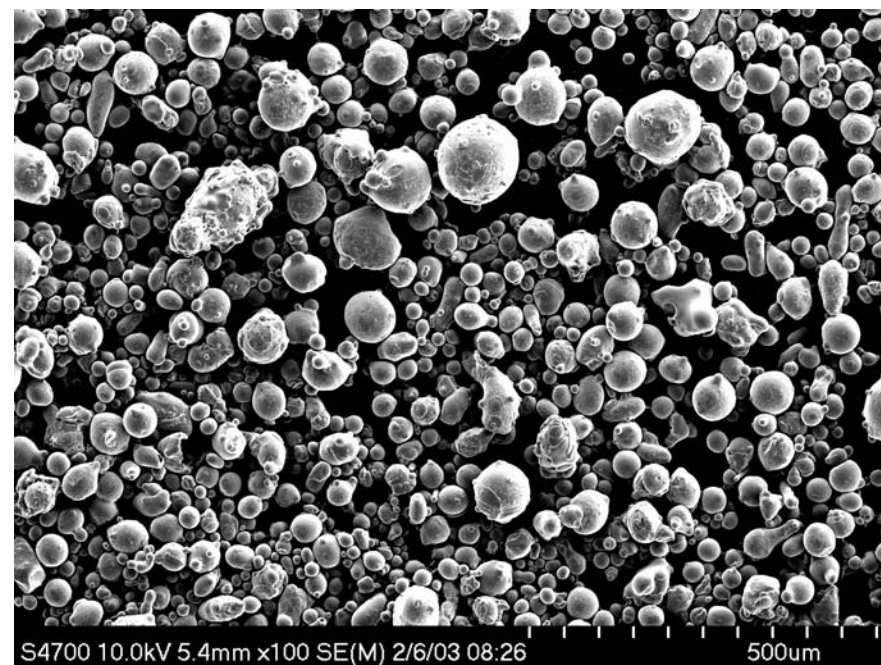


# Technical Data

Hardness	Vickers (300g)	Rockwell C (Conversion)
<i>as-HVOF sprayed</i>	<i>1034</i>	<i>69.4</i>
<i>heat treated</i>	<i>1364</i>	<i>73.5</i>



XRD Pattern DAR 35 Powder



DAR 35 Powder FSEM

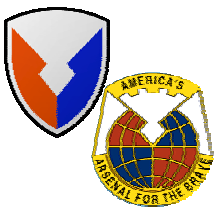


# Processing Approaches

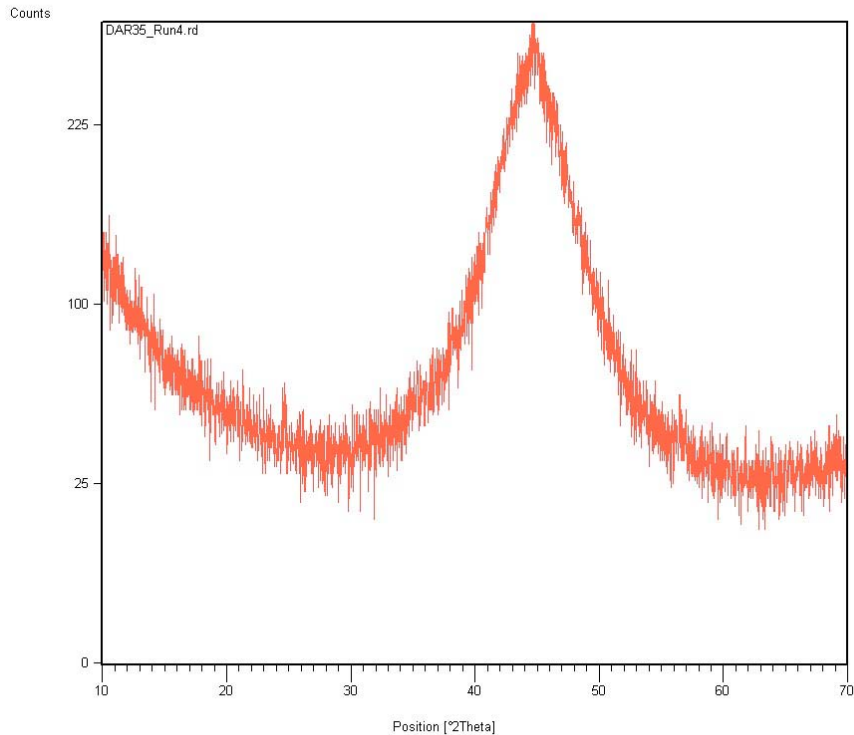


- HVOF
- Plasma Arc Spray
- Cold Spray
- Spray Forming

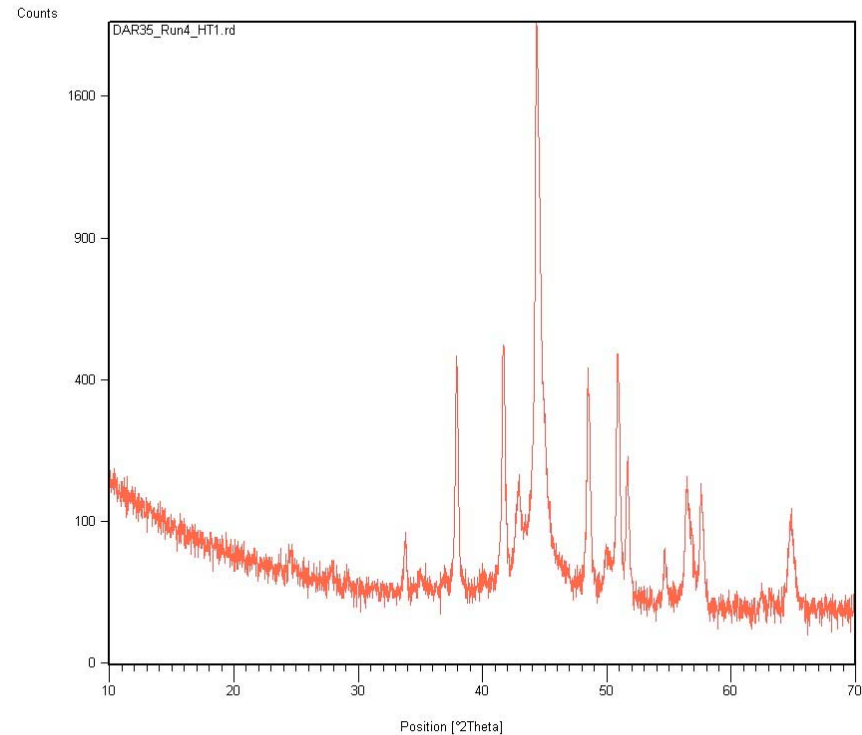
**Maintain Amorphous and/or Nanocrystalline Structure**



# Accomplishments Utilizing HVOF Technology



**XRD Pattern HVOF Diamond Jet**  
**Amorphous Microstructure**

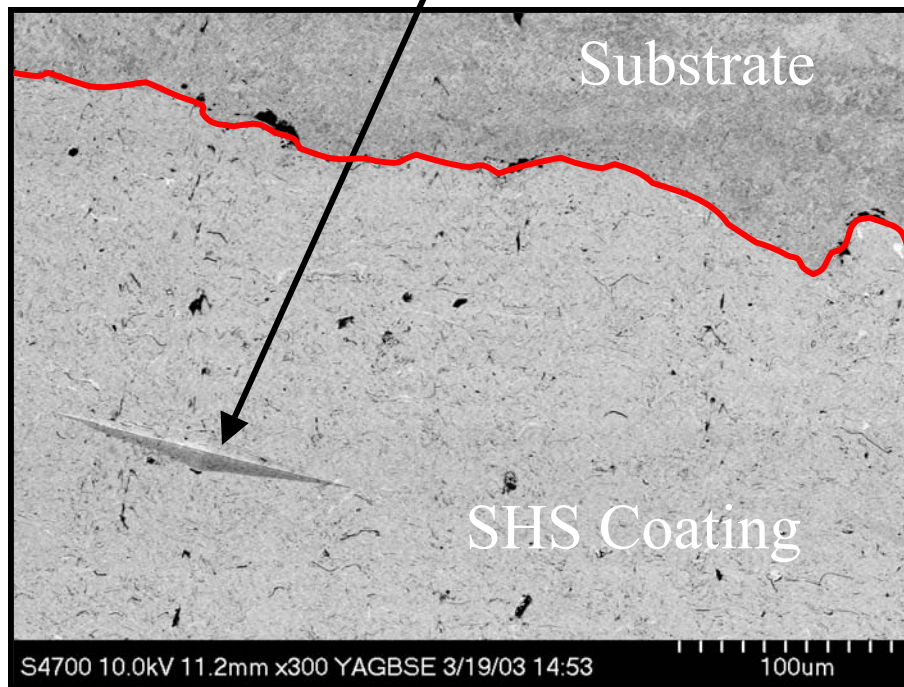


**XRD Pattern HVOF After Heat Treat**  
**700° C for 10 min. Nanocrystalline**



# Microstructural Analysis of HVOF Coating

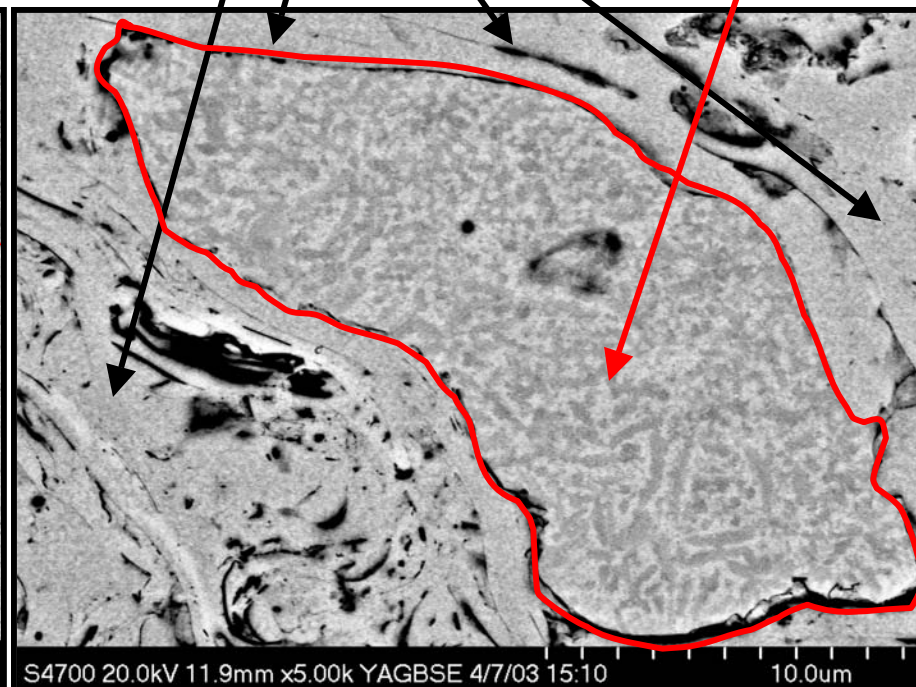
Hardness Indent



HVOF As-Sprayed Microstructure

Amorphous

Nanocrystalline



Microstructure After Heat Treatment



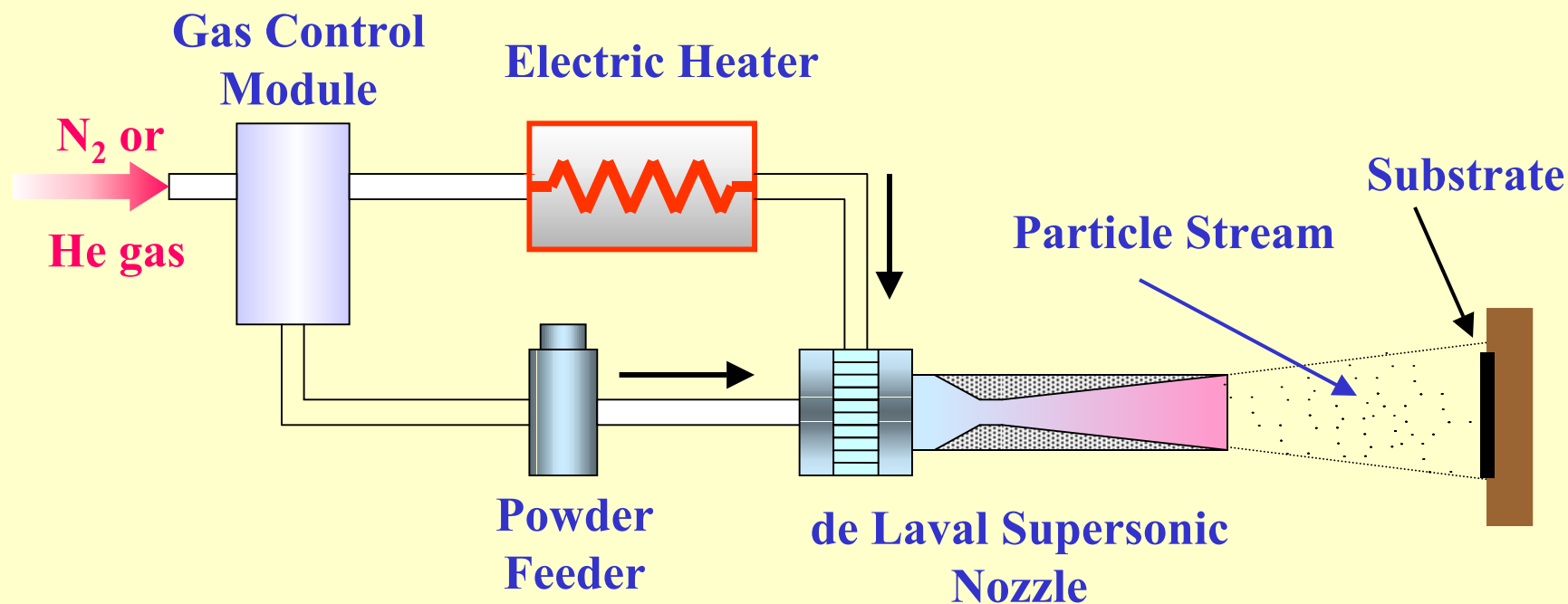
# Supersonic Particle Deposition

**•ARL -WMRD is the only facility within DOD and one of only a few entities in the USA to have a fully operational SPD System.**

Main Gas Stagnation Pressure 100-500 psi   Gas Temperature 0-1300°F   Main Gas Flow Rate 30-100 CFM

Powder Feed Rate 10 to 30 pounds/hour

Particle Velocity 300-1500 m/sec.





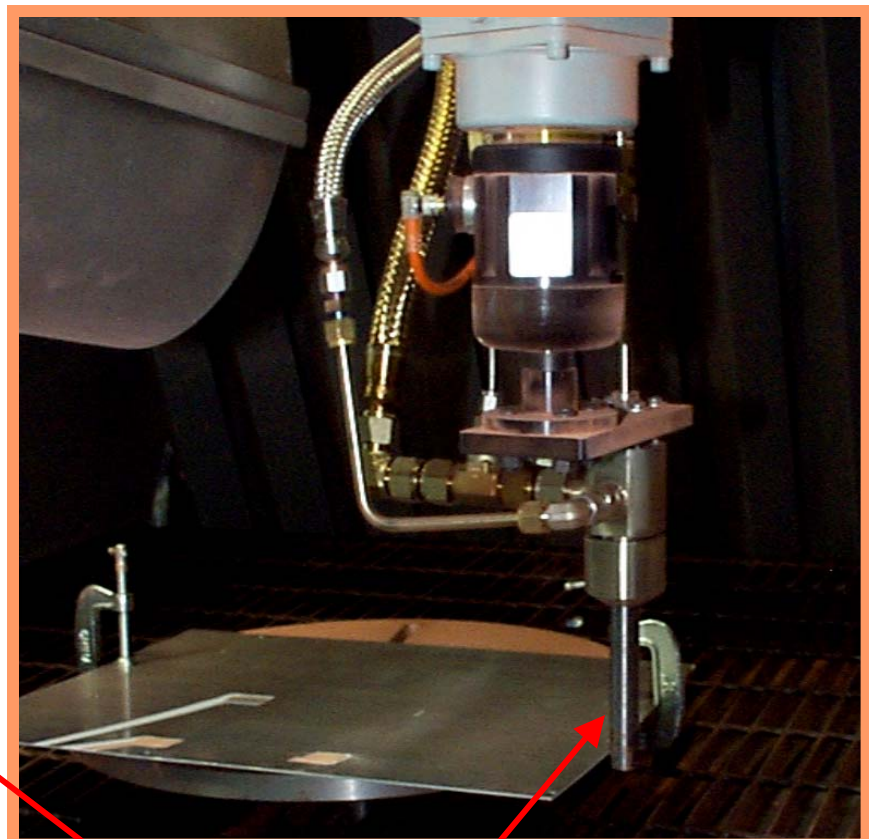
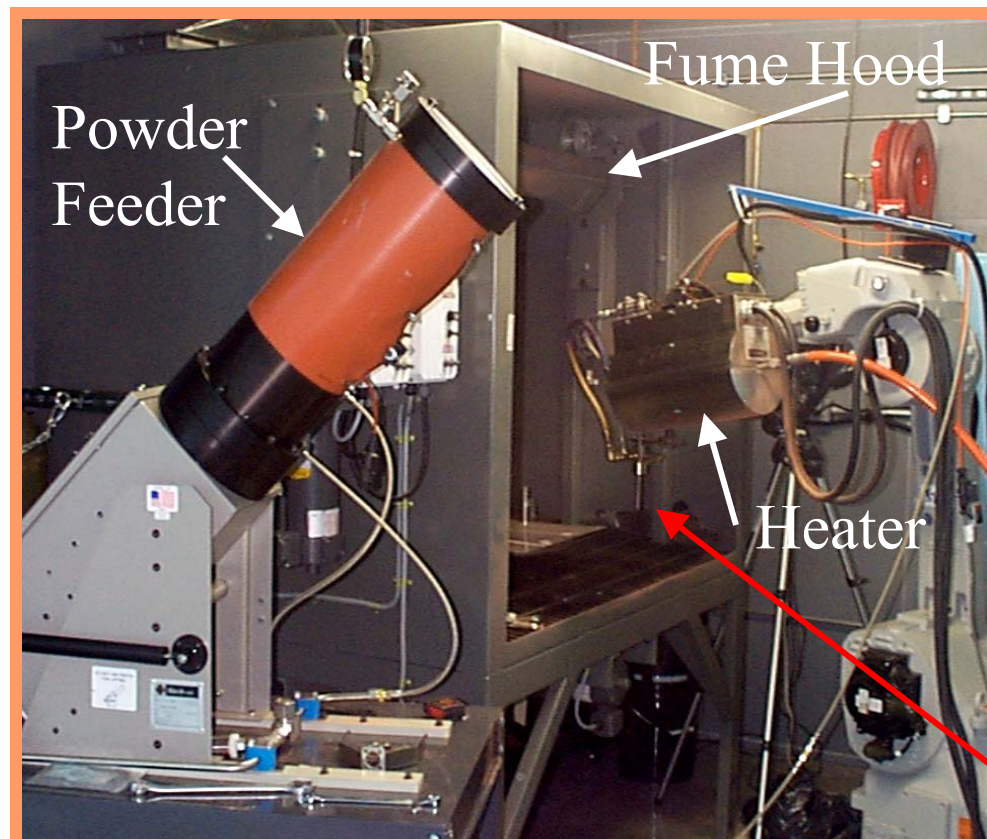


# Cold Spray Advantages

- **High deposition rates**
- **Deposition efficiency greater than 70%**
- **Porosity less than 1%**
- **Low temperature deposition**
- **Solid state bonding**
- **High density, low oxide content**
- **Young's modulus 85% of bulk material**
- **High thermal & electrical conductivity**
- **Electrical conductivity near bulk material values**
- **Low residual stress**
- **Compressive residual stress**
- **Produces free-standing structures**



# ARL SPD System

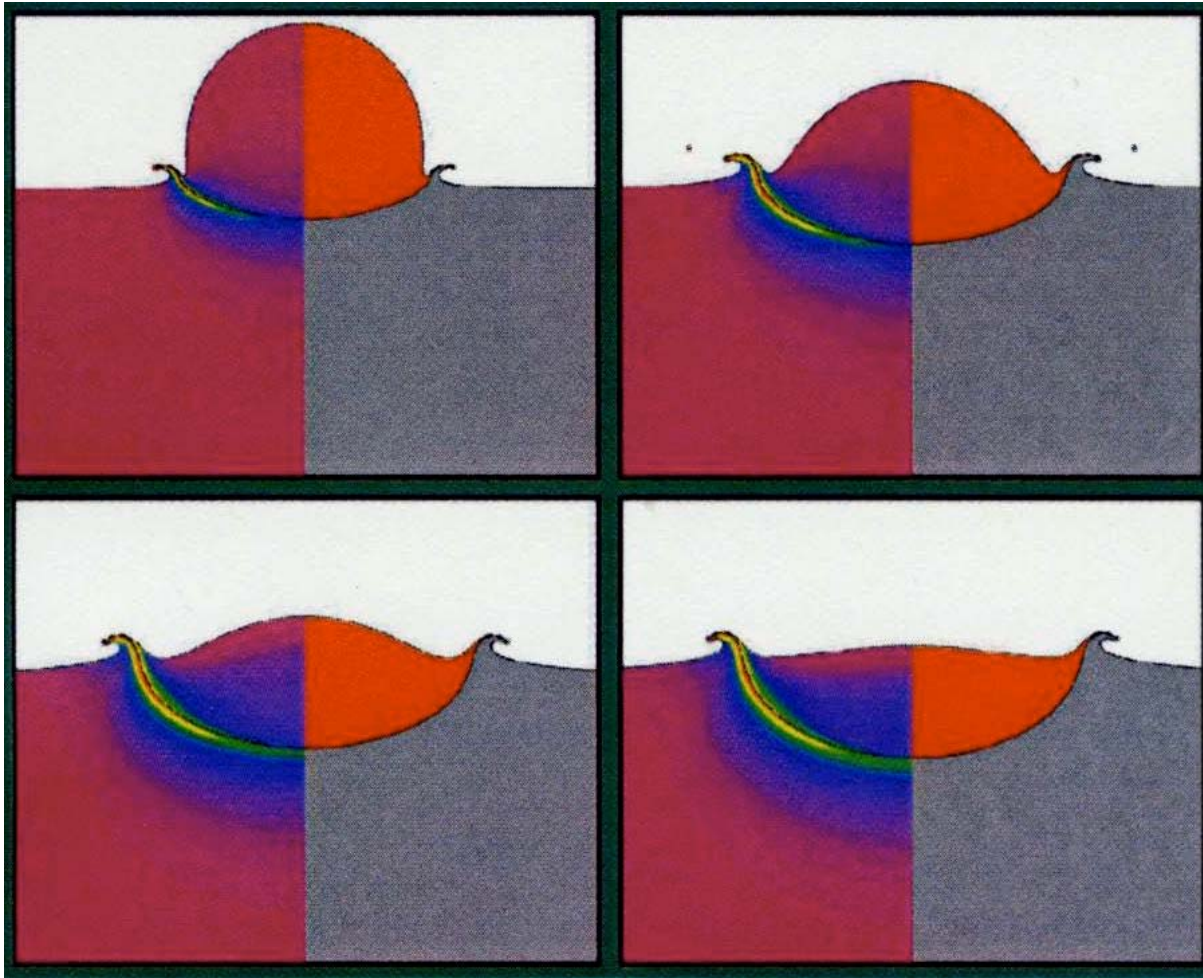


Robotically Controlled

Spray Nozzle



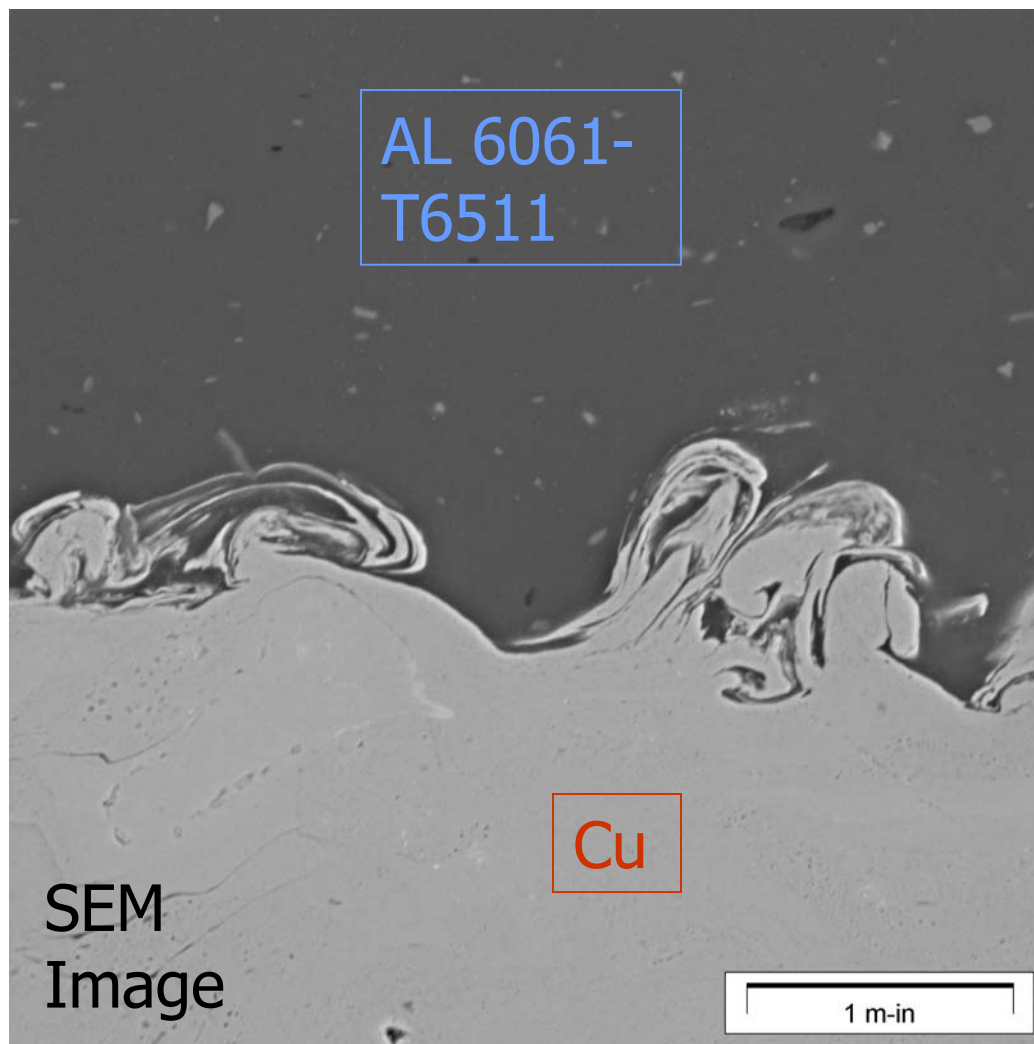
# Particle Impact



From Dykhuizen et al, J. Thermal Spray Tech, Dec 1999.



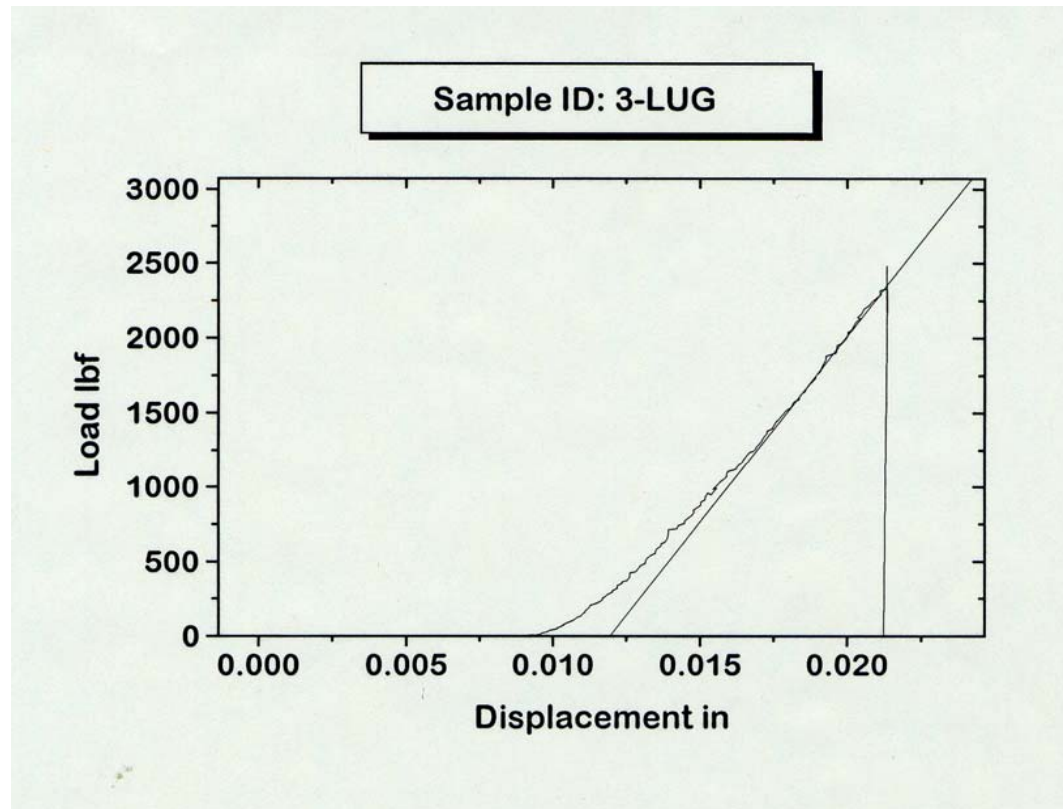
# Copper Deposition on Aluminum







# Copper on Aluminum



Shear Test Bond Strength = 11,650 psi



# Typical Process Parameters

Carrier Gas

Gas Pressure

Temperature

Standoff

Traverse Speed

Powder Size

Powder Feed Rate

Nitrogen

300-400 PSI

400-450 °C

25 mm

100mm/sec

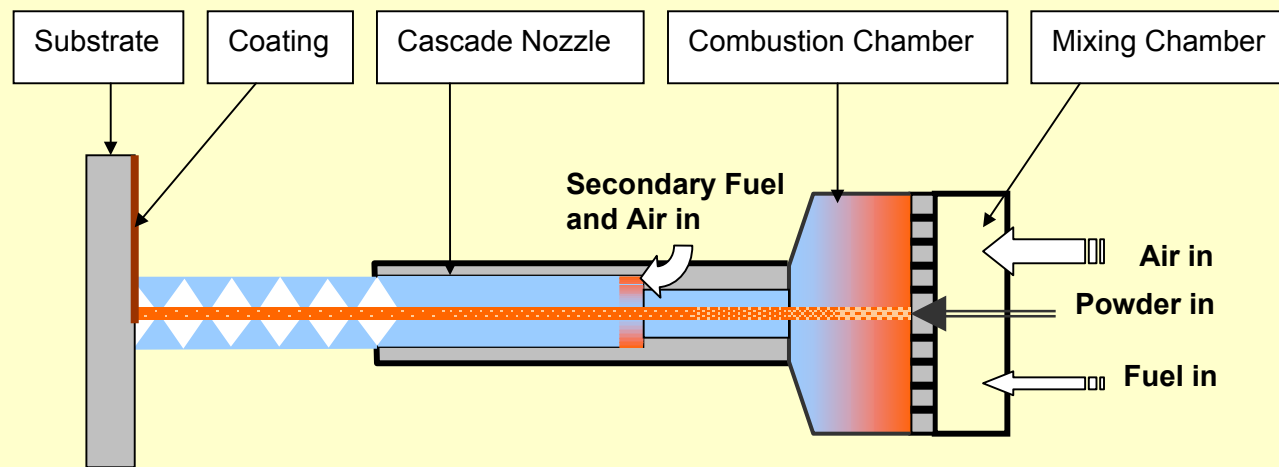
5-45 microns

20-40 g/min





# HVAF Gun Assembly





# Benefits of HVAF

- Expands metal, alloy and carbide coating capability while retaining benefits of Cold Spray
  - High Productivity Rate and Increased Coating Thickness
  - Low Porosity, Non-Oxidized Coatings
  - Coatings are essentially free of residual stresses